BASIC WORK ON THE LIFE CYCLE OF SOME AUSTRALIAN SNAILS

By C. F. McLauchlan

Students and collectors from time to time have contributed notes and articles on the habits of our native snails. But apparently no serious long term biological research has been undertaken. It is not a study which can be undertaken in a year or a month, and the amount of work required is remarkable, if continuous records are to be kept. In this article, notes are gathered together in the hope that a little more will be added to the knowledge we already have. The work will deal mainly with *Strangesta capillacea, Meridolum jervisense* and a new species of *Meridolum*, but other types will be added at suitable points for comparison. It must be remembered that locality and climatic conditions are the main deciding factors in the habits of snails. We cannot expect inland snails to act as do those on the coast: the carnivorous snails, *S. capillacea* (Paryphantidae), living in luxury in the overgrown, disused gardens about Sydney Harbour, eat numbers of common garden snails at certain times of the year, and often deposit their eggs at any suitable time during the year, whereas in the bush near Church Point worms are their main food, and egg laying is confined to spring and autumn. Again, at West Wallsend, the carnivorous snails live mainly on *Vercularion* (Helicarionidae), which are abundant, and appear to confine the egg laying to one month, in spring only, when two or three clusters can be found under almost any log. Therefore, the habits discussedhere must apply to the above species, and to some very near related types and to the localitiés mentioned, which are in New South Wales. *S. capillacea* was described from Port Jackson from an immature shell of 4 whorls, 20 x 10mm, which was described as depressed, yellowish with no decussating spiral lines. A normal adult specimen, is depressed in shape, is reddish brown, 25 x 15 mm, and has 5¼ to 5½ whorls, the ribs of the last whord being heavily dented by spiral lines, giving them a wavy appearance, this point helps in separating it from its near neighbours. The umbilicus fits loosely over the sharpened end of a pencil. The shell is carried about three-quarters of the way back along the animal's body. The animal is 2¼ inches long, inky grey on top, median line pale grey, the mantle has golden flecks over a colourless base. There are quite a number in some gardens about the shores of the harbour. They are true Sydney shells, the range is very limited, extending from Palm Beach to Hornsby, thence to Parramatta and south to National Park, but seldom if ever as far as the causeway at Waterfall, the northern limit of *S. fricata*, this latter species following the ranges as far as the Shoalhaven. Attempts to cross *S. fricata* and *S. capillacea* have failed, but live snails were found near Waterfall having the shell spire of *S. fricata* and the body whorl of *S. capillacea*, these animals mated successfully with the former one season and the latter the next season, which shows that the line which separates these two species is very thin. Space does not permit us to go into the numerous experiments that were carried out. But it is sufficient to say that this species may be the original of the types *fricata* and *capillacea*.

Between the Hawkesbury and the Hunter River the larger species *Strangest sanguinolenta*, sp. nov. (fig. 5), occurs, the best shells coming from Mt. Sugarloaf, near West Wallsend, and extending along the length of the Sugarloaf range. It is a bright varnished chestnut when new, a normal shell of $5\frac{1}{2}$ whorls is 25 x 12.5 mm high, a maximum shell of 6 whorls reaching 30 x 14 mm. Animal medium brown with a blood-red mantle.

On the other hand, there are our Southern *Meridolum jervisense* (Hadridae), 21 mm x 17 mm high, shaped somewhat like the common garden snail, with light brown shells, and reddish brown bands below the suture, and a dark umbilicus patch. Then in the semi-rain forests, and living in very damp, overgrown situations beside the Pork Hacking River, National Park, is the larger snail *Meridolum marshalli,* sp. nov. The female-predominating shell is depressedly globose, solid, 36 mm wide x 26 mm high, the male-predominating shell is taller and narrower. The colour is a clouded brown, with a darker subsutural band, surrounded below by a yellowish band; the umbilical patch is reddish brown, surrounded above by a yellow band; body whorl large, rounded; keel obsolete; whorls $6\frac{1}{4}$; aperture large, slightly descending, bluish brown within; lip thickened and reflected all round, bluish white; a thin callous between the margins; columella expanded, closing the umbilicus. Waterfall, National Park (near Sydney), N.S.W. type in the Australian Museum (coll. A. J. Marshall). It appears to have practically lost its habit of aestivation, which may account for the number of dead shells found after each severe dry spell: its food, like most of the Hadridae, consists of some tender grass shoots and succulent growths, vines, over-ripe berries and native fruits, anything soft and pithy, such as decaying humus mixed with soil and grit. Some pieces of leaf or bark found in the stomach were 3 mm x 3 mm, and some pieces of quartz 1 mm x 1 mm. They puddle this humus soil, with the moisture available, before eating it. They can hardly be called entirely herbivorous as any worms, decaying insects, termits, eggs, and ants mixed with the soil all help with the diet. They like wet, tender eucalypt leaves and nettles, and they such at the white paint fungus on logs, and the fine hairy fungus which covers the damp soil under timber and leaves.

Hadra bipartita of North Queensland lives in the soil beneath the plants of the cultivated peanuts, beans and peas, and comes out at night to eat the leaves and flowers, also they are very fond of fallen over-ripe apples and the less acid stone fruits.

The M. *jervisense* living in the scrubs or on the dry rocky hills are much tougher snails; they depend a great deal on rain and dew, but if these are not available they just hide away in the soil at the edge of a log, at the base of a tree, under a rock, or under the loose bark some feet up a tree, aestivating until the rain falls, and they can remain in that state for months during the hottest and driest part of the year, although it seems that a period of six months is a fair limit for Australian land snails to survive this treatment. The belief that some of our snails remain for a year or more buried feet under the sand or soil during extremely long droughts appears not quite true, as they come to the surface quite frequently and sop up the dew which falls at times in practically all our dry areas. The coastal *Meridolum,* for instance, living in the tea-tree scrub behind the sandhills, comes out from its hiding-place each night a heavy few falls, or during the day if it rains—not to eat, as one might think, but to sop up the moisture until its body looks like a filled sponge, then it takes in as much as possible between its body and shell. Returning to its hideout, it releases the water a little at a time on to the humus soil, working it into a sloppy mess before eating it. If no such soil is available, it will work on a decaying leaf, by squirting water over the surface and then working it over with the lips until a jelly-like substance is formed, which is rasped off before repeating the process.

The aborigines evidently dug them up from about the base of trees, from under bark and logs, and toasted them over fires on their middens; it was no trouble then to shake the animals out of the shells. To-day the discarded bleached shells, along with old sea shells and bones, can be found in countless thousands on these old middens, particularly on the sandhills at Mona Vale, north of Sydney. The distribution of this type, a new species which I name M. *middenense* (fig. 4) is between Stanwell Park and Broken

Bay, but does not extend inland far from the beaches. To-day a live specimen true to the middens type is seldom found owing to the clearing of the land for golf links and homesites. The live shell is brown above, pale under, with a subsutural dark band on body whorl only, and small dark umbilicus patch; of 6 whorls, 24 mm x 16 mm; depressed; the animal is gold over chocolate, with brown eyestalks, with marked anatomical differences from M. *jervisense* and M. *duralense* and they will not mate with either of these species.

As we are on the subject of food, let us deal with the carnivorous snails, such as *Strangesta capillacea*. Although once a bush snail, it now can be regarded as a true Sydney garden snail, as it occurs in most gardens throughout the metropolitan area, and is really becoming scarce in the bush. Although they are carnivorous and the common garden snail *Helix aspersa* is quite plentiful, yet the number of the latter they eat is very small; in fact, only about one-eighth of the total food consumed. In the native bush S. *capillacea* and S. *fricata* consume even less native snails than that, which is quite understandable. Nature must strike a balance, because *Meridolum* and other native snails increase at a very slow rate, and would soon be eaten out entirely. More than half the food intake is composed of worms, soil, insects, larvae and eggs. Most of the snail's time, day and night, is occupied in churning up the surface soil hunting for this food, and during this time, humus soil up to about one-quarter of the total amount of food intake is eaten. If the soil insects, and small worms, are not caught by mouth, then they are trapped in the mucus between the snail and the shell, to be eaten when the snail reutrns to the open. With some *Strangesta* and *Vercularion* the mucus containing the insects and other food moves down the grooves of the body, to the grooves on the side of the foot, and passes to the tail, where it becomes a congealed lump, and is then eaten by the snail. Some of the *Vercularion* live in pairs, in which case the hunter has to be quick to benefit from its own work, or its mate will get the meal. The method adopted by *Strangesta* when feeding upon worms is very interesting. They work through the damp rubbish until they come upon the worm from the tail end, then with a quick roll of the radula a portion of the worm is raked into the crop, the remainder of the worm wriggles off into the rubbish, but eventually the snail will catch up with it. When another snail is the victim, *Strangesta* opens its mouth wide, the radula is thrust out, being rolled at the same time, the teeth which normally lie flat become erect at the opening. The *Strangesta* moves forward, burying its mouth into the body of its victim; the radula acts much like a conveyor belt, raking the food into the stomach. The carnivorous snail appears unable to bite the pieces off, and continues to rake in more and more. If the snail can be pulled from the mouth of the *Strangesta* it looks much like a long chewed stringy piece of meat. The carnivorous snails have a most peculiar habit of thrusting the full length of their tail into the empty shell of their latest victim; the tip of the tail goes deep into the spire; the tail end only, and not the front end, is thrust in. They may be able to absorb through the skin of the tail some film left in the shell by the victim. It may be noted here that *Strangesta* holds two pieces of quartz within the mouth; they are apparently used in place of the palate or jaw which it does not possess, and even if the snail is without food for some time, it still retains the stones. In one case a piece of quartz and a piece of gold were being used.

Several of the carnivorous types have a dislike for introduced snails. A number of the large Queensland S. *maxima* were placed in a glass house, which soon became overrun with *aspersa; maxima* refused to eat any of them and persisted in finely churning the soil hunting for worms.

These records are taken from snails living under natural conditions, but for comparison it may be necessary to refer to notes taken from those kept in captivity. Snails kept in captivity do not give a true picture of their real habits, as can be noted by the number of *aspersa* eaten by *Strangesta* when kept in captivity and the few *Meridolum* eaten under natural conditions.

Research into Life Cycle

The following is a basic work on the life cycle of the snails mentioned above and applies to many others of the families Hadridae and Paryphantidae. By studying the snails in their natural habitat and checking the results by keeping them in captivity it has been possible to arrive at the facts concerning their mating, egg laying, growth and length of life. To study the biology of S. *capillacea,* M. *jervisense, Sphaerospira fraseri* and some of the Helicarionidae, a gully was selected, bordered by cliffs and enclosed at the bottom by water, well timbered, and with palms and undergrowth, also with a permanent creek. The snail population was collected and numbered with paint, descriptions and measurements taken, and the snails then replaced. At regular intervals the logs and stones and drifts of leaves were turned over and notes taken on all aspects of the life cycle, including the migration of each snail, its liking for the thick undergrowth beside the creek, or the middle third of the hillside, or the top third which was dry, and under the cliffs; in addition, the temperature readings and notes on the weather were kept.

As can be imagined a considerable amount of patience and work were involved, especially as it had to be done in one's spare time, but I am sure the results have been worth while.

Let us deal first with the mating. This takes place during the night or early morning, after a day or two of rain, between spring and late autumn. A most interesting point about a mating pair of Hadridae found in the bush is the difference in size, shape, and age of the two shells. For example, take M. *marshalli* (fig. 1). The shell of the oviparous or egg-laying animal is a little depressed, with protoconch whorls loose, flat and wide, aperture wide open, the lip well reflected; the animal mature, two or more years of age.

The shell of its mate (fig. 2), the ovidormant animal (egg-laying ability is dormant), is taller, narrower, darker, with a smaller protoconch and aperture, the lips uneven and sharp, and not more than two years old.

A pair of M. *duralense,* for instance are so different as to have originally been regarded as two distinct species. One has a very depressed appearance, resulting in a strong keel and measuring 21 x 14 mm high. Its mate is narrow and tall, 19 mm x 15 mm high, the body whorl so rounded as to have only a mark for a keel. On rare occasions snails are found which have broken these rules, but mostly they have been injured, although at odd times they are apparently normal.

There is a slight difference in the shell and animal of *Strangesta capillacea* compared with the *Meridolum* pair. In this case the shell of the oviparous animal is deeper than its mate, with a larger aperture, spire taller, protoconch wider, flat and loosely wound, the umbilicus narrower, the shell darker, with the animal lighter. In the very young *Strangesta* these shells can be separated from their companions by their much darker colouring and lighter animals, and they are contained in about two-thirds of the eggs in each batch. When selecting pairs in 1947, I found that success in mating and fertility in the eggs were certain when the pairs were arranged as above, and with the oviparous partner being a mature or old shell, and its ovidormant mate a young shell of 10 to 24 months. The most remarkable point is, that in captivity the ovidormant snails of both *Strangesta* and the Hadridae have never laid eggs, no matter whether they are young or old, and watching those under natural conditions, I have not been able to prove that they do, either. I have used the word ovidormant simply to distinguish the animal with this trait from its oviparous (egg-laying) mate. The egg-laying ability is definitely dormant and is subject in some genera and species only. With my present knowledge of the anatomy of this snail there is no reason why the ovidormant ones could not lay eggs, excepting that the female organs are not completely developed. The anatomy of the ovidormant animal, of the tall shell of M. *jervisense,* q and g (fig. 6a), shows the male reproductive organs predominating (the female organs are relaxed and underdeveloped). When dissected alive the spermatozoa have a tendency to coil, and are in greater numbers compared with those in the other animal.

In most *Meridolum*, apparently, this snail acts as the fertilising agent the first two years of its life, from then it takes no further part in the mating. In *Vercularion freycineti* (Helicarionidae) (fig. 3) the animals are male and female alternately. In the larger *Fastosarion superbus* there is a definite male and female in animal and shell. There is no difficulty in observing the female predominating animal of the pair depositing its eggs during the spring, and sometimes during the late autumn, and, generally speaking, the last act of its life is to produce a batch of eggs, and the oldest and largest dead shells are often found lying over the eggs.

In the anatomy of the oviparous animal (fig. 6)—the flatter shell of the mating apir—the female reproductive organs are fully developed internally and externally, the spermatheca no longer relaxed. The male organs are relaxed, the penis small, and what may possibly be an obsolete dart sac is vestigial (D.S. obs., fig. 6a), and considerable stimulation is needed before the male organs become active. Self-fertilisation has yet to be proven. My dissections, to date, show that it is not evident in Australian snails, although a single *Meracomelon* from South Australia kept in a box alone, somehow managed to produce fertile eggs after 2½ years.

At this point it is advisable to mention the ability of some *Meridolum* to produce the young alive. This was first noticed when young snails of two whorls were found in a bottle with M. *bowdenae*, sp. nov. (see McLauchlan, 1951), from Springwood, N.S.W., two days after being collected. When this happened the second time, it was decided to examine them carefully. To do this, all live shells collected during the spring were washed, examined closely with a lens, and placed in clean jars; examination continued each day. No food was given for three weeks, but a little tap water was run down the inside of the jar on to the animal. During this time three snails produced young alive. No. 1, three young; No. 2, eight; and No. 3, eleven. Several laid batches of eggs. To date four species, M. *scotti*, a Wallsend species, *bowdenae* and *depressum*, all mountain species, have been noted as having produced young alive, and in dissections I have found live young, varying from 1½ to 2½ whorls, within the vagina. This trait has been only briefly mentioned and must be dealt within a separate article when more notes and material are available.

In North Queensland, where heavy rains occur during summer and autumn, both Hadridae and Paryphantidae take advantage of the early winter months as well as the spring and summer to lay their eggs, and the eggs of these three season batches generally hatch. But eggs laid during May by snails of southern N.S.W. are usually a failure, although if the winter be very dry and the days sunny a few will hatch. If a fairly wet summer and autumn is experienced, oviposition takes place from January until early winter, and the young are produced up to about May.

November hatched snails usually lay their eggs during the following spring. The autumn hatched snails will often lay a few eggs the following autumn, but mostly carry over until the following spring, a period of 17 months.

Strangesta capillacea place their batches of up to 50 eggs in shallow covered holes in the muddy sides of creeks. S. *sanguinolenta*, from south of the Hunter River, place theirs on the open ground under logs, where they are prey to any egg-eating creature. Here Nature has a curious sense of humour. The parent remains with the eggs and acts as a protection to some extent, but when the young appear she eats them.

The Illawarra S. *fricata* place their eggs under leaves in damp patches in semi-rain forest, where they are a harvest for the Lyre birds. The Blue Mountain S. *revera* mostly place their eggs away in hollow logs, covering them with the loose wood fragments. Once I found a batch in a wire hole in a fallen fence post, and two of the eggs were just on the point of hatching.

The *Meridolum* prefer to bury their eggs deeply under stones or timber. But the larger Queensland Hadridae place theirs under logs, mostly at a point where any rain which falls on the log will drip near the eggs and keep the earth moist. The average is about 32 eggs, laid in two batches, two months apart. In carefully attended testing boxes the approximate period of gestation is 92 days and the incubation period 61 days. If the snails are disturbed during egg-laying they may cease altogether, or may continue later. In nature, the weather is the deciding factor in the time taken to hatch the eggs, and the time taken can be from 9 to 16 weeks. For example, *S. capillacea* deposits its eggs in a small hole, and after the eighth week they need enough rain to soften the covering of the eggs; a day or two later a warm drying wind is necessary, then the top layer of eggs can be heard cracking. This must be repeated three times to hatch at least half the batch, and may cover a period of up to 26 days, the remaining eggs at the bottom of the hole seldom hatch. In cases where the weather is unsuitable, the snails can remain in the unhatched eggs for about four months before drying. On the other hand, I have released the tiny creature from the egg at 40 days. The young snail, at this time, is only $1\frac{1}{4}$ whorls, white, able to move the body, but not the shell. If allowed to remain in the broken egg case it will go on developing, and after a week can be seen to put its head outside the egg covering and suck at the earth; at the end of another week it is strong enough to leave the egg cover altogether. Under the microscope the first sign of life within the shell is a tiny mass of semi-transparent jelly, about half a whorl in length, on which is a tiny limpet-like parchment cap about one-eighth of a whorl and darker than the animal; the striae are quite visible, and it hardens upon contact with the air. Liquid surrounds the animal. As the snail grows the "parchment" spreads along and around the body, becoming shell-like, though frail at one whorl, but is not a true shell until $1\frac{1}{2}$ whorls have been reached; the animal is now able to move slowly in and out of its shell and move about within the egg case until it is too big to move any longer. During this period it rasps off the inside of the egg cover from which it apparently gets the material to build the rest of the tiny shell. Generally the newly-hatched snail has a shell of 2 to $2\frac{1}{2}$ whorls; that is, it has passed the protoconch stage and is developing the first of the adult shell and sculpture.

The cycle cannot be completed without some data on the life span and growth of several of our snails. With carefully kept notes and measurements of hundreds of Paryphantidae and Hadridae, alive and dead, it is possible to form a fairly reliable chart.

Taking the age first, we can refer to notes on *S. capillacea* and *S. sanguinolenta*. The oldest specimens hatched from eggs under my observation are over $3\frac{1}{2}$ years old in December, 1950. Their parents were in their third and fourth year when the eggs were laid. Most of them are in natural surroundings in the open bush, and they are still healthy and still fertile. This gives us definite proof that 6 or 7 years of age is not the limit of their lives, though in the bush they are very lucky to live to the second year.

Then what is the limit of their lives? Dead shells found lying across their last batch of eggs, near Church Point, and at Mount Sugarloaf, West Wallsend, and in old neglected gardens, probably reached a maximum of $8\frac{1}{2}$ years. Some shells of other countries live beyond this, which means that until we have actually observed our snails through to the limit of their lives we cannot give a definite answer.

After keeping records and having studied hundreds of *S. capillacea, fricata, revera, sanguinolenta* and *maxima* in their native habitats and over a period of four years, I have no doubt that only one snail in about 3,000 juveniles will live to an extremely old age. Of every 1,000 eggs produced only one-third will hatch, half of these will be destroyed before their first year; of the other half only about three dozen will be alive between the first and second years, one dozen between the second and fourth years, and only about four snails will be living between the fourth and fifth years.

On the other hand, the Hadridae have a better record: M. *jervisense, corneovirens, gulosum* and *Sphaerospira fraseri* show about 100 adults from every 1,000 juveniles alive between the first and second years. Half of these will be alive between the second and fourth years, and about 2 between the fourth and fifth years. Two in 1,000 die of old age.

It is quite understandable why Nature produces so many young snails, yet so few survive. In the initial stages the young carnivorous animals are too small to hunt for food, they remain together and prey upon each other; when old enough to roam they depend upon the young of the herbivorous snails. This habit of preying upon one another is one of the disadvantages in breeding carnivorous snails. It not only keeps their numbers down to a limit when released, but it makes it necessary to keep only 3 or 4 young together in each section, and then they have to be carefully watched.

Although I have reared some 4,000 carnivorous snails from the egg stage to the releasing stage of one year, I must have reared thousands more to the age of from a few days to a few months, only to see them eaten by their companions. Of one batch of 50 young, only 6 were left at the end of 3 months, 5 measured 3.5 mm and one 9 mm. It was easy to see where the others had gone, yet plenty of young *H. aspersa* and worms were available to them.

In the bush many native snails are destroyed by worms, possibly two species of nematodes; these colonies get in behind the mantle and work their way far up into the shell; the irritation set up causes the animal to remain retracted; it goes off its food and dies. In the *Turrisitala* shells these worms are very numerous.

Fungus is another source of trouble; once it attacks the snail it soon becomes limp and dry looking, the mucus dries up, the animal becomes leathery, it remains retracted with the limp, dry tail lolling out of the shell. It may be encouraged to come out of the shell and eat, but it soon dies.

The following is a fairly accurate chart of the size of the shells according to their age—that is, the normal shells—because under adverse conditions they may remain at 3½ whorls for over 12 months, which is only the juvenile growth. These non-growing periods also occur in the older shells and are always marked by a decided break in the shell. In some of the larger groups these breaks are a constant factor in all the normal shells. Normally at 12 months there are between 4¼ and 4½ whorls, and increase ½ whorl each year to the third year. From the third year the *Strangesta* increase very slowly, reaching about 5½ whorls at 5 years.

With the Hadridae the outer lip is well reflected at 4 years, and increases in bulk only from then on. While *Strangesta* increases at the rate of one-eighth of an inch after five years, the sculpture becomes rugged, with each year marked by a ridge. The mantle sags, allowing the top of the body whorl to flatten or dip at the aperture.

S. *capillacea* normally measures 25 mm wide, but one very old frail shell tipped the ruler at 28 mm wide, and must have reached the maximum in years.

Malnutrition affects the snails to some extent, evidently being caused by the deficiency of minerals and vitamins in soil and food, and here are the results of some research into the matter.

The young from the eggs of a form of M. *jervisense,* a shell ¾ inch high, brown, with an even sculpture, were reared on sand containing some shellgrit, the only food allowed being the decayed vegetation of the tea-trees, worms and sandhill grasses. The protoconch was normal as in the parent, but from there on the rest of the shell became stunted with a small aperture, the sculpture rugged, the shell thin, the colour insipid, and reduced in size to ⅝ x ½ an inch high. Here we have proof that if a species lives under certain conditions, generation after generation, it can become a sub-species, or even a new species.

The young of M. *corneovirens* living on sandy, well-grassed land with mostly wattle trees, and eating a large amount of green food, is a thin greenish shell with a fine even sculpture. When reared for three years on a heavy humus soil containing a large percentage of hydroxide of iron, the shells became a bright chestnut, larger, much thicker, with the sculpture heavier.

S. *capillacea* became grotesque, deformed, too thin to handle, and of the palest yellow, with the aperture descending abnormally, when reared on washed quartz sand and carefully fed entirely upon young *Meridolum*.

Some specimens of M. *duralense* found at Pennant Hills were living in the decayed rubbish at the base of *Angophora* or Sydney Red Gum trees. This rubbish is made up of the bark which contains some of the red gum, tannin, soil and leaves; it is of a dark purple colour, acid, with a strong smell, and wet. The *duralense* shells inhabiting it were of a black violet, which fades to a dark reddish brown when old. Normally the shells are brown. To test this humus, the green M. *corneovirens* from Mulgoa were reared on it; the first generation shells were brownish and the second generation violet. It may be noted that the coloration of the first generation in most shells tested was very little affected, but results were obtained in the second generation.

Now the shells of M. *marshalli* are a dark brown, but their offspring are a uniform green-yellow, with the usual dark subsutural band, because they were reared on the food and soil of the green M. *corneovirens* from Mulgoa.

Dissections show that the snails' various organs are able to separate various minerals and vegetable colours and granules, and certain cells retain them, and apparently deposit them into the composition of the shell. Free colours and dyes have very little effect, but if a mineral is taken up by a plant and the snail continually eats that plant the colour of the shell is affected.

We can darken shells by feeding iron to a plant and feeding the leaves to the native snails. Alum fed to hydrangea bushes, and the leaves to the snails will give a variegated shell. At least two or three generations of the snail are needed to show any results in colour.

At Cockle Creek, near Newcastle, the surface is a sulphide soil, and peculiarly enough all the snail animals have red on them, and either reddish or green shells. The slug-snails *Parmavitrina* and *Vercularion* both have a red foot, with orange flecked mantles. *Strangesta* has a blood-red mantle and reddish shell. *Meridolum* has a flecked orange mantle, and the native slugs the brightest of red on the foot and triangle; of course, they normally have a red or pink foot and triangle, but not as red as these, and the body of most of the above is bronze. Some minerals the soil contains contribute to these colours. If we feed copper and sulphate of iron in a weak diluted form to certain plants and feed the leaves to native snails, we get subsutural and peripheral bands on species of shells that originally had no bands, suggesting that these present species come originally from shells which had bands, and the cells which deposit the bands in the shell are only dormant in the present shell.

Limestone and limestone vegetation have very little effect on the shells, but food continually soaked in lime water will strengthen and whiten the shells and has a tendency to elevate them, especially the small cylindrical types. And we get elevated beautifully banded and striped shells from a pink light brown, alkaline soil, which contains calcium carbonate and is taken from above granite.

The function of colouring the shell and the colour in the animal are quite independent, which accounts for albino animals with coloured shells and vice versa. In 873 M. *marshalli* examined between Waterfall and Wollongong, N.S.W., seven were of the former and twenty of the latter; one was entirely albino in both animal and shell. The colouring in the shell is mainly microscopic particles of minerals. The colouring of the animal is mainly melanin particles in the epidermis cells assisted by mineral particles. The shell and the colouring are not entirely an attempt by Nature to camouflage or build a cover for the animal; they are both purely excreta of the blood and cells. The material which forms the shell is excreted by the mantle cells and is hardened by contact with the air, froming a crust. Thus the shell is formed because the material is not discarded completely.

Albinism is the complete breakdown of the melanin making and carrying cells, but a coloured shell can still result, because the system still carries the particles to the mantle and they are there discarded in the shell composition. If the cells are even in size, then the result is a unicoloured shell; if larger cells occur at certain points, larger or more abundant particles are secreted and excreted, resulting in a darker band.

Minerals are altered by other minerals and are again altered by the digestive juices. Lime lightens colours in both animal and shell. The presence of ferric oxide and hydroxide of iron in the soil and humus forms various shades of red. Carbon, sulphur, sulphide of iron result in blood-red colouring. Magnitite has a tendency to blacken shells. An abundance of chlorophyll granules will give a greenish colour, but combined with lime turns shells yellow.

Minerals and other granules vary considerably over a given area of food and soil and the ability of the animal to separate and retain the particles is the deciding factor in the variation of a colour in different snails.

This subject has been dealt with only briefly, and really needs a separate paper, as considerable analysis is involved, together with dissecting and breeding. There are no set rules, and each species and the particular soil and food need separate investigation.

Inquiries being made by research students of other countries as well as Australia into the possibility of controlling pest snails by the use of carnivorous snails makes it necessary to give a few details as to the best methods to adopt.

Cultivate the carnivorous snails in shallow trays with humus soil and worms, keeping the juveniles separated from the adults, and the larger juveniles from the smaller. Feed them on the young of the pest snails to let them acquire the taste. Some carnivorous snails dislike foreign pest snails.

When introducing them to the garden or plantation do not introduce a few dozen or so, and spread them about, hoping they will increase naturally; they will not increase to any great extent. In fact, they hardly increase at all, varying in numbers from year to year, because they destroy each other and the hot weather kills off most of the larger ones. The best method is to rear hundreds of them to the age of 12 months—at the stage they oviposit. Next select the time of year the pest snails are hatching, say, mid-spring and mid to late autumn, and release hundreds close together where the pest snails are most numerous. Release the following batches fairly near and surrounding the first released, not down the other end of the land. Before the next hatching of the pest snails occurs, make a survey of the released snails and it will possibly be found it is necessary to release several hundred more to bring the original numbers up to strength.

Now here is a point. During the warm months these snails will aestivate, and this is unfortunate, because it is at this very time that the young of the pests are developing, so that when the carnivorous snail is on the roam again, at the commencement of the wet season, the pests have become too large to handle. To overcome this it is advisable to release the first batch as the pests are hatching, and the second batch about two or three months later.

As most pest snails like the drier parts of the land and the others the dampes*, I found it necessary to go a step further and gather the aestivating

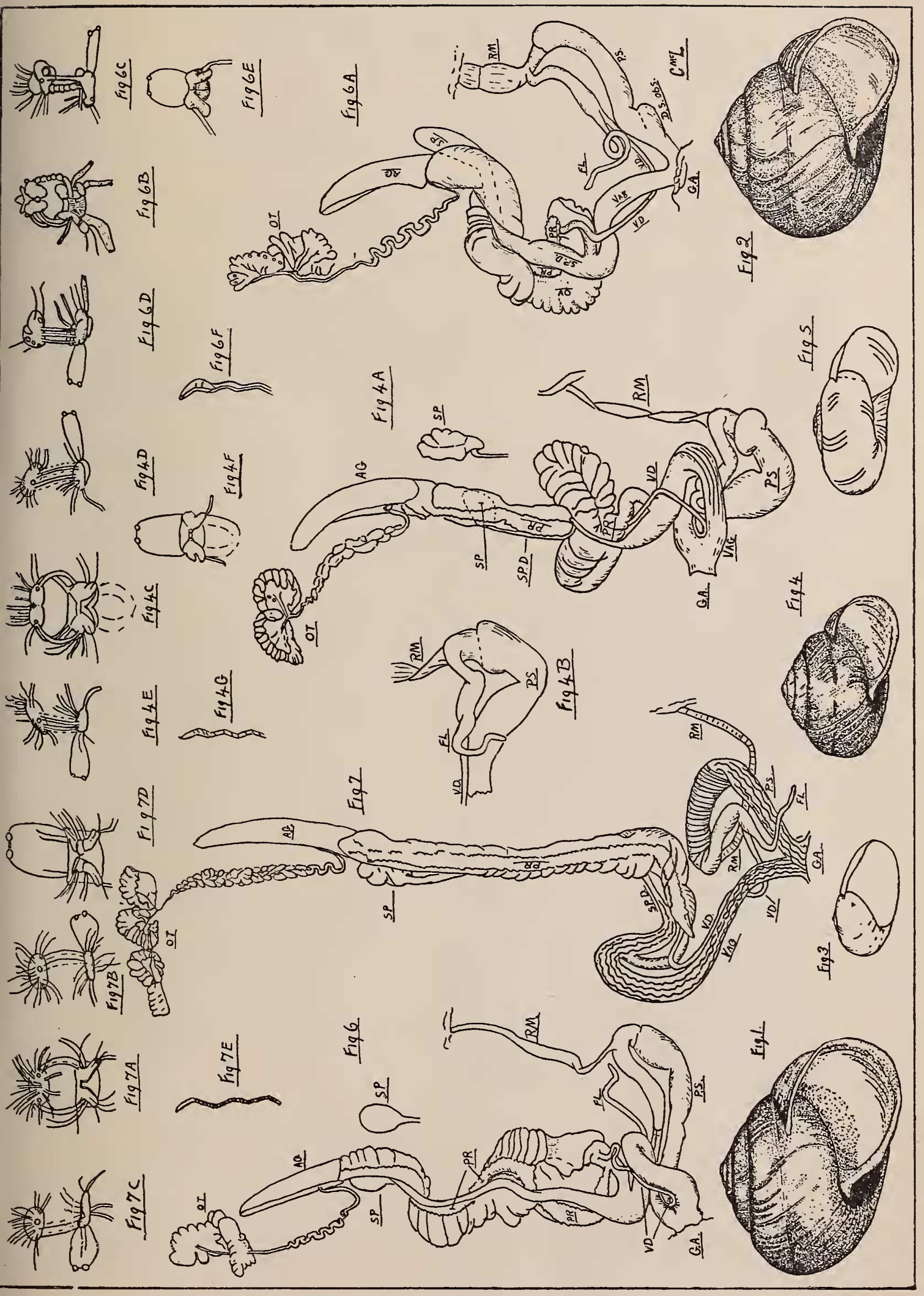

Figure 3. Australian Snails (see page 36 for Explanation).
C. F. McLauchlan del.

carnivorous types and release them either at the top of the land, or poke them into the cracks and crevices where the pests were hidden. But only by continuous supervision can the carnivorous snail succeed; the latter is not a success on its own.

References

Iredale, T. (1938).—A Basic List of the Land Mollusca of Australia—Part III., Austr. Zool., ix., p. 83.

McLauchlan, C. F. (1951).—Austr. Naturalist (in the press).

Summary

Observations on the biology of New South Wales snails of the genera *Meridolum* and *Strangesta* with incidental notes on others, with particular reference to their breeding, genitalia, and the effects of food on shell coloration. *Meridolum marshalli,* new species from National Park. M. *middenense* and *bowdenae* and *Strangesta sanguinolenta,* spp. nov., are dealt with further in McLauchlan, 1951.

Explanation of Plate

Fig. 1.—Shell of *Meridolum marshalli* McLauchlan. Female predominating. The more depressed shell of the mating pair. Causeway, Waterfall, N.S.W.

Fig. 2.—Shell of *Meridolum marshalli* McLauchlan. Male predominating. The taller shell of the mating pair. Fully grown. Causeway, Waterfall, N.S.W.

Fig. 3.—Shell of *Vercularion freycineti* Ferussac. Epping, also Chinaman's Beach, Mosman, and Cooper's Park, Bellevue Hill, N.S.W.

Fig. 4.—Shell of *Meridolum middenense* McLauchlan. Male predominating. The taller shell of the mating pair. Mona Vale, N.S.W. 4a, Anatomy. 4b, Male reproductive organs. 4c, Central nervous system. 4d, Right side. 4e, Left side. 4f, Base. 4g, Anterior end of spermatozoon. (Tail 32 times length of the head) x 1,000.

Fig. 5.—*Strangesta sanguinolenta* McLauchlan. Female predominating. Mt. Sugarloaf, West Wallsend, N.S.W.

Fig. 6.—Anatomy of *Meridolum jervisense* Quoy and Gaimard. Female predominating. From animal of the more depressed shell of the mating pair. Northern end of Jervis Bay, N.S.W.

Fig. 6*a*.—Anatomy of *Meridolum jervisense* Quoy and Gaimard. Male predominating. The taller shell of the mating pair. Northern end of Jervis Bay, N.S.W. 6b, Central nervous system. 6c, Right side. 6d, Left side. 6e, Base. 6f, Anterior end of spermatozoon (Tail 42 times length of head, tapers to a fine point) x 1,000.

Fig. 7.—Anatomy of *Meridolum duralense* Cox. Male predominating. Taller shell of the mating pair. Dural, N.S.W. 7a, Central nervous system. 7b, Right side. 7c, Left side. 7d, Base. 7e, Anterior end of spermatozoon (Tail 40 times length of head) x 1,000.